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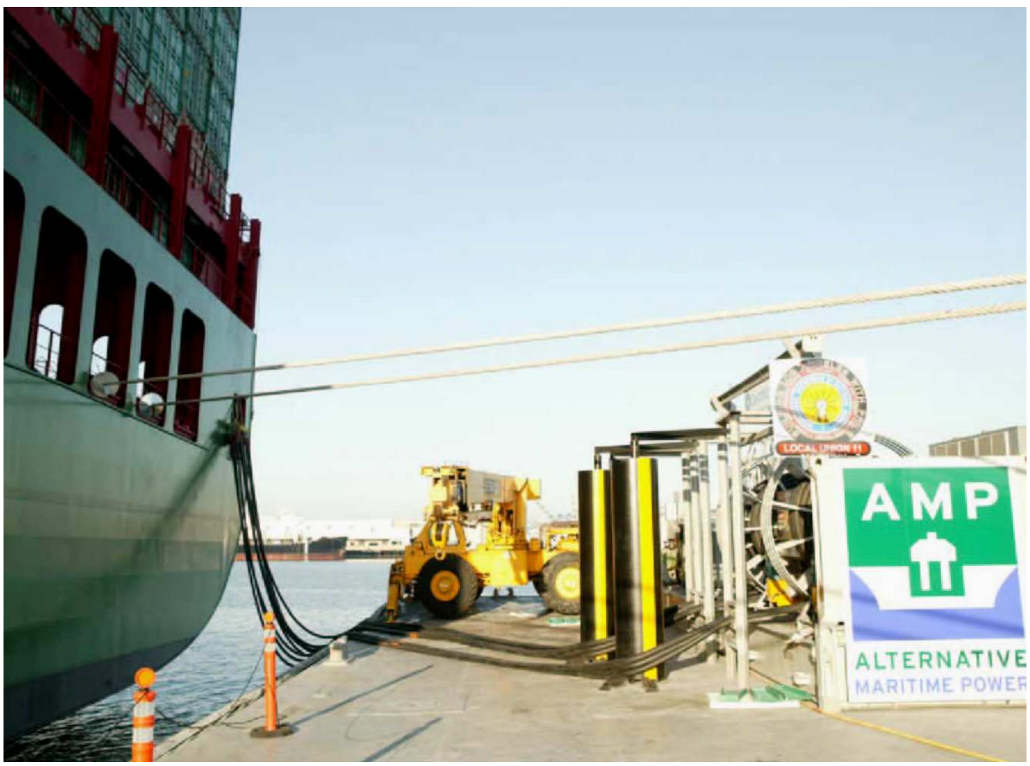
California Environmental Protection Agency
AIR RESOURCES BOARD

Evaluation of Cold-Ironing Ocean-Going Vessels at California Ports



Stationary Source Division
Project Assessment Branch

March 2006

The Air Resources Board (ARB/Board) staff is soliciting comments on this draft report, *Evaluation of Cold-Ironing Vessels at California Ports*. This report presents an analysis of the feasibility and cost effectiveness of cold-ironing ships when the ships are docked at California ports.

Please submit your comments to Mr. Mike Waugh, manager of the Program Assistance Section, by April 3, 2006. Your comments may be submitted via email to mwaugh@arb.ca.gov , or by phone at 916-445-6018, or mail to:

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Any questions you may have on this report can be directed to Mr. Mike Waugh at 916-445-6018 or Mr. Grant Chin at 916-327-5602.

Evaluation of Cold-Ironing Ocean-Going Vessels at California Ports

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BACKGROUND

Purpose of the Report

This report presents an analysis of the feasibility and cost effectiveness of cold-ironing ocean-going vessels while docked at California ports. Cold-ironing refers to shutting down auxiliary engines on ships while in port and connecting to electrical power supplied at the dock, thus eliminating virtually all emissions from a ship while it is in port. (Cold-ironing is also referred to as "shore power" and alternative maritime power). The term "cold-ironing" comes from the act of dry-docking a vessel, which involves shutting down all on-board combustion, resulting in the vessel going "cold." Without cold-ironing, auxiliary engines run continuously while a ship is docked, or "hotelled," at a berth to power lighting, ventilation, pumps, communication, and other onboard equipment. Ships can hotel for several hours or several days.

This report supports emission reduction goals outlined in the 2003 South Coast Air Basin State Implementation Plan (SIP), the Air Resources Board (ARB or Board) draft Goods Movement Emission Reduction Plan, and the Board's Diesel Risk Reduction Plan.

The 2003 revisions to the South Coast Air Basin SIP required the ARB to evaluate the options for requiring cold-ironing of ships that frequently visit South Coast ports. Additionally, ARB staff recently released a draft *Emission Reduction Plan for the Ports and International Goods Movement in California* (dated December 1, 2005). The plan identifies strategies for reducing emissions created from the movement of goods through California ports and into other regions of the State. The draft Emission Reduction Plan identifies numerous strategies for reducing emissions from all significant emission sources involved in the goods movement, including ocean-going vessels. ARB staff identified cold-ironing as a potential emissions reduction strategy. Finally, the Board, through its Diesel Risk Reduction Plan, established a goal of 85 percent reduction in diesel PM in California by 2020. Cold-ironing is an effective diesel PM reduction measure that supports that goal.

Summary of the Analysis

If all ships visiting California ports were cold-ironed, hotelling emissions would be reduced by 95 percent from the emissions level achieved when distillate fuel is used in the ships' auxiliary engines. Oxides of nitrogen (NOx), particulate matter (PM), and hydrocarbon (HC) emissions would be reduced by 22, 0.4, and 0.6 tons per day, respectively, based upon 2004 emissions using distillate fuel. If all ships making three or more visits per year to a California port were cold-ironed—a more likely scenario—the overall hotelling emissions would be reduced by 70 percent. NOx, PM, and HC emissions would be reduced by 17, 0.4, and 0.5 tons per day, respectively. If ships making six or more visits a year to a California port were cold-ironed, the overall hotelling emissions would be reduced by about 50 percent.

Container ships often visit California repeatedly, making about half of the total ship visits to California, and would be expected to account for most of the emission reductions from a strategy that targeted frequent visitors for cold-ironing. Passenger ships would also account for a significant amount of the potential emission reductions. Finally, because most of the ship visits in California are to the Port of Los Angeles/Port of Long Beach (POLA/POLB), about 70 percent of the emission reductions would occur at POLA/POLB for all three scenarios: 1) all ships are cold-ironed; 2) only ships making three of more visits a year to one port are cold-ironed; or 3) only ships making six or more visits a year to one port are cold-ironed.

Health Impacts of Hotelling Emissions

Hotelling emissions from auxiliary engines are significant contributors to particulate matter from diesel-fueled engines (diesel PM), California's most significant toxic air contaminant. Communities adjacent to the ports are exposed to elevated cancer risk and other health impacts from these hotelling emissions. As indicated in a recent Air Resources Board (ARB/Board) risk analysis conducted for the ports of Los Angeles and Long Beach, "Diesel Particulate Matter Exposure Assessment Study for the Ports of Los Angeles and Long Beach," 20 percent of total diesel PM emissions at these ports comes from hotelling emissions. Other sources of diesel PM include emissions from ship transit and maneuvering, cargo-handling equipment, and rail and truck operations. The analysis concluded that the hotelling emissions contribute 34 percent of the total population-weighted health risks due to diesel PM posed to the residents in the surrounding communities. In fact, of all the sources of diesel PM at the ports, hotelling emissions resulted in the largest area (2,036 acres) where the potential cancer risk levels were greater than 200 in a million in the nearby communities.

In addition to local health risks, hotelling emissions of NOx also contribute to regional ozone and fine particulate matter ($PM_{2.5}$) levels. Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Exposure to fine particulate matter, including diesel PM, can also be linked to premature death and a number of heart and lung diseases.

Current Emission Reduction Efforts at California Ports

California is home to three of the largest ports in the nation, as well as several other major ports. The San Pedro Bay ports of Los Angeles and Long Beach comprise the largest container port complex in the nation and the third largest in the world. The Port of Oakland is the seventh largest container port in the nation. Since 2000, container traffic has increased by 40 percent at the ports of Los Angeles and Long Beach. By 2020, cargo movement at California's ports is expected to triple from 2005 levels.

With this expansion in mind, the major California ports are already pursuing extensive emission reduction strategies, including cold-ironing. The Port of Los Angeles drafted, but has not yet adopted, a “No Net Increase (NNI)” strategy, the purpose of which is to roll back and maintain air emissions from the Port’s activities to October 2001 levels. One of the control measures identified in the report is an enhancement of the Port’s Alternative Maritime Power (AMP) program. The current AMP program is a voluntary program intended to reduce hotelling emissions from ships by providing shore power to container and passenger ships. As an incentive for this program, the Port will provide up to $810,000 to defray the cost of adding shore-power equipment on ships that will call at the Port for at least five years. One NNI proposal would go beyond these voluntary measures and require all passenger ships and all other ships calling at the port five or more times a year to be cold-ironed.

The Port of Long Beach has adopted a Green Port Policy that is intended to guide the Port’s operations in a “green” manner. The Port has committed to providing shore-side power to all new and reconstructed container terminal berths and other berths as appropriate. Through lease language, the Port will require selected vessels to use shore power and all other vessels to use low-sulfur diesel in their auxiliary generators. According to the Third Quarterly Report for the Green Port Program, dated December 13, 2005, cold-ironing projects are being developed at three berths at the Port—one of them a voluntary project with the tenant.

In the Bay Area, the Port of Oakland has indicated that it is planning on evaluating the feasibility of adding shore power to its terminals in the future. The Port of San Francisco has recently completed a feasibility study for adding shore power to its new passenger ship terminal at Piers 30-32 and will now develop more specific cost estimates and pursue potential funding for building a shore power project at the terminal.

The Port of San Diego is considering providing shore power to passenger ships calling at the port. The port is developing a conceptual design for including shore power at its B-Street Pier, which the Port plans to redevelop.

Cold-Ironing on the West Coast

Cold-ironing is already occurring at ports on the West Coast, including California.

The U.S. Navy cold-irons ships while in port at bases all over the world. The Navy connects to shore power as a matter of routine and has done so for several decades. The ships are also hooked up to water, sewer, communications, and steam while docked. Cold-ironing is routine at the San Diego Naval Station.

The Port of Los Angeles retrofitted the China Shipping Terminal (Terminal 100) to include a shore-power infrastructure. Two ships began connecting to shore power in June 2004. According to the Port, there are now currently 15 ships that are equipped to plug into shore power while at the terminal. During the first three quarters of 2005, 28 out of 39 ship calls to Terminal 100 used shore power. Although an impressive start, this still represents a small fraction of overall container ship visits to Los Angeles. In 2004, the Port had 2,940 container ship visits.

Princess Cruises began cold-ironing their ships docked in Juneau, Alaska in 2001 and Seattle, Washington in 2005. According to Princess Cruises, there are currently six ships that are equipped to cold-iron in Juneau and two ships in Seattle. In 2005, five ships from Princess Cruises cold-ironed in Juneau a total of 93 times—16 percent of the 586 total ship visits to Juneau. At the Port of Seattle, 13 passenger ships are scheduled to make 193 visits in 2006; 40 of these ship visits (or 21 percent) will be made by two shore-power-equipped ships owned by Princess Cruises.

Four dry-bulk ships cold-iron while docked at USS POSCO Industries' steel facility in Pittsburg, California. The ships are also equipped with selective catalytic reduction (SCR) technology. Connection to shore power began in 1991 as part of the POSCO facility's plan to mitigate emissions from an expansion.

There are other cold-ironing projects planned for California. The Port of Los Angeles is currently building a shore-side infrastructure at berths 212-221 to provide power to a container ship (NYK Atlas) when in port. The NYK Atlas was equipped with shore power capabilities when built in 2004. Shore-side construction is expected to be completed by early 2006.

The Port of Los Angeles has already built a shore-side infrastructure at Pier 400, although no ships calling at this terminal are currently equipped to connect to shore power. Shore-side infrastructure will also be built at berths 206-209. The lease for the container terminal's new tenant, P&O Nedlloyd, will require that 70 percent of ships calling there be connected to shore power within three years. According to the Final Environmental Impact Report for this Project, it is expected to take two years out of the five-year lease period to build the shore power infrastructure. Additionally, the Port has indicated that they will begin designing a shore-power infrastructure at their passenger ship terminal (berths 91-93) once they receive a firm commitment from a tenant to utilize shore power when in port.

At the Port of Long Beach, British Petroleum (BP) will equip two of its new Alaskan-class tankers with shore-power capabilities when they are built in 2006. The ships will call at berth T121, where the Port has committed to developing the shore-side infrastructure. According to BP, each ship is expected to visit the berth six to 20 times per year. There were 212 total ship visits to berth T121 in 2004. If the two ships visit a total of 40 times per year, they could represent about 20 percent of total ship visits to this berth, based on 2004 numbers.

Evergreen Marine Corporation announced in March 2005 that their new S-class 7024-TEU container vessels will be equipped with cold-ironing capabilities. (A TEU stands for “twenty-foot equivalent units” or a container with the dimensions of 20’ x 8’ x 8.5’). Two of the ten S-class ships ordered by the Evergreen Group have been delivered, although there are currently no matching shore-side power installations at the Evergreen terminals in California.

As can be seen from the examples above, cold-ironing is technically feasible. Shore power is currently being used or planned for passenger ships, container ships, bulk ships, and oil tankers, as well as having been practiced routinely for decades at U.S. Navy ports all over the world.

COST-EFFECTIVENESS METHODOLOGY

Staff collected data for 2004, the most recent year with complete data. The data came from several sources: the State Lands Commission, the Marine Exchange database for the ports of Los Angeles and Long Beach, data supplied directly by the Port of Oakland, responses to ARB’s Ocean-Going Vessel Survey for 2004, published passenger ship schedules for the Ports of San Diego and San Francisco, and extensive web searches for shipping data, port information, and electricity tariffs. Staff sought to corroborate the data where possible. Where discrepancies occurred, staff selected either the data that was more common to most of the sources or the more primary source of data.

Staff identified 18 California ports for initial consideration of cold-ironing, as listed below:

Avalon-Catalina	Monterey
Benicia	Oakland
Carquinez	Pittsburg
Crockett	Redwood City
El Segundo	Richmond
Hueneme	Sacramento
Humboldt	San Diego
Long Beach	San Francisco
Los Angeles	Stockton

According to the State Lands Commission database, 1,906 ocean-going vessels visited California ports in 2004. Staff divided the ships into six categories: container ships, passenger ships, refrigerated cargo ships (reefers), tankers, vehicle carriers, and cargo/bulk ships. Staff conducted cost-effectiveness analyses for these ship categories. Table ES-1 shows ship visits to California in 2004.

Table ES-1: Ship Visits to California Ports in 2004, by Ship Category

Category	Total Ships Visiting California	Total Ship Visits	Number of Ships Making 3 or More Visits to a California Port	Total Visits from Ships Making 3 or More Visits to a California Port	Number of Ships Making 6 or More Visits to a California Port	Total Visits from Ships Making 6 or More Visits to a California Port
Container	592	4,727	426	4,404	247	3,297
Passenger	44	642	22	573	18	549
Reefer	55	270	24	227	16	192
Tanker	370	1,864	86	1,370	37	1,001
Vehicle Carrier	227	748	62	391	14	146
Bulk	618	1,362	66	429	12	147
Total	1,906	9,613	686	7,394	344	5,332

Table ES-2 shows the hotelling emissions from these ships.

Table ES-2: Hotelling Emissions from Ocean-Going Vessels (TPD)

Year	NOx	PM	HC	SOx
2004	24.2	2.1	0.6	15.5

ARB staff calculated cost effectiveness using three major sets of variables: ship categories, ship electrical requirements, and pollutants reduced. Due to varying power requirements, transformers are needed to supply the proper voltage to nearly all of the ships. These transformers either have to be located within the port infrastructure or on the ships. ARB examined both of these scenarios. Currently, most ocean-going vessels use residual fuel; however, the Board adopted an Ocean-Going Vessel Auxiliary Engine Fuel regulation in December 2005. This regulation requires that most of these ships use cleaner distillate fuel when in California waters, starting in 2007. Because of this requirement, ARB staff calculated emission benefits and cost-effectiveness values based on the use of distillate fuel only.

Furthermore, staff looked at three overall scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed.

Finally, staff calculated the cost-effectiveness values on the basis of pollutants reduced: 1) "all pollutants" (NOx, PM, hydrocarbons, and oxides of sulfur [SOx]); 2) NOx-only reductions; and 3) PM-only reductions.

Based on previous cold-ironing projects and analyses (China Shipping, Princess Cruises, ENVIRON Corporation Report for the Port of Long Beach and Port of San Francisco), ARB staff estimated that the average cost for retrofitting ocean-going vessels is $500,000 per ship without an onboard transformer and $1.5 million per ship with an onboard transformer. Shore-side infrastructure costs are site-specific and can vary widely. The largest portion of overall shore-side infrastructure costs is usually the modifications required to the existing electrical infrastructure to bring adequate power to specific terminals. For the purposes of this report, staff estimated that the average cost for providing shore-side infrastructure—without additional shore-side transformers—to be $3.5 million per terminal. The cost for a shore-side transformer and associated equipment is an additional $1.5 million per berth. For example, if a terminal consists of three berths, then the total cost for the shore-side infrastructure would be $8 million ($3.5 million for general terminal costs and $4.5 million for three transformers).

Recurring operating costs include energy costs (electricity or fuel), labor, and routine equipment maintenance. Staff used utility tariff schedules to estimate electrical costs for cold-ironing. Electrical tariff schedules vary among utilities, but they all typically include monthly fees, demand charges, time-of-use charges, and seasonal adjustments. Overall, the cost of electricity from the grid depends upon how much capacity is needed (i.e., the "demand," the maximum number of megawatts needed at any one time) and how much electricity is used annually. The most expensive average electrical rates occur if the electrical demand is high (a lot of megawatts are needed, as with passenger ships), but the actual annual usage is low (few ships being cold-ironed). In this case, rates can be over one dollar per kilowatt-hour. Conversely, for most tariff schedules, the more electricity one uses, the lower the average electrical rate. In this situation, rates can drop down to 8-9 cents per kilowatt-hour.

Currently, electrical energy costs are higher than residual fuel energy costs, so a cold-ironing project will incur a net cost for energy consumption. The relative price difference between electricity and distillate fuel varies according to tariff schedule and usage. For this report, ARB staff assessed an electricity charge for cold-ironing, then subtracted a fuel cost savings for shutting down the auxiliary engines. Based on published costs for fuels in the spot-fuel market in mid-summer 2005, staff estimated distillate fuel to cost $485 per metric ton. This market value corresponds to eleven cents per kilowatt-hour for average energy use.

For all ship categories but the tanker category, staff included the cost of using union electricians to both connect and disconnect electrical power for these ships. Staff estimates that it would take one hour to connect a ship and one hour to disconnect a ship from shore power. Staff assumed that three electricians are necessary to both connect and disconnect the electrical power, and that the direct cost of this labor is about $600. If, however, electricians are not already on duty, costs could be much higher, as labor contracts require that workers, once called, be paid for an entire shift. In the case of passenger ships, staff assumed that two electricians would connect and disconnect electrical power—all other assumptions regarding labor costs are the same. For the tanker category, it was assumed that the additional labor would be met with existing resources; thus, there would be no additional cost.

It is important to note that, as cold-ironing becomes routine, average operating costs reduce significantly, both from an electrical use standpoint and a labor standpoint.

RESULTS OF THE COST-EFFECTIVENESS ANALYSES

The cost-effectiveness values in this report assume that all of the costs and the benefits will be borne by California. As cold-ironing becomes commonplace, other ports—whether U.S. or foreign ports—will reap the benefits of cold-ironing when they install the necessary infrastructure to service the ships retrofitted to cold-iron in California. Therefore, the ship-side costs should be allocated to these other ports. The cost effectiveness presented here is overestimated based on the total emission reductions that are likely to be achieved.

Because most of the emission reductions from cold-ironing will be NOx, staff chose to present cost-effectiveness values for NOx reductions only in the body of this report. In addition, these NOx cost-effectiveness values were calculated using 0.1 percent sulfur distillate fuel and assumed the transformers were located on the shore. The shore-side transformer scenario was used because staff believes this to be the most likely approach to implementing cold-ironing. The 0.1 percent sulfur distillate fuel was used because the recently adopted fuel regulation requires its use statewide by 2010. A discussion of staff's cost-effectiveness results for all other pollutants, including diesel PM, and scenarios analyzed, and the corresponding cost-effectiveness tables, are included in the appendices to this report.

Table ES-3 provides a summary of the NOx cost-effectiveness analyses for the six ship categories visiting POLA/POLB (except Oakland data is also included for the container ship category as explained later in this section). Staff selected POLA/POLB to illustrate the data because all ship categories visit these ports, 55 percent of all California port calls in 2004 were made to POLA/POLB, and 60 to 70 percent of the potential emission reductions from cold-ironing would occur at these ports. These data are illustrative of the cost-effectiveness results in general and have been simplified from the more complex and detailed analyses contained in the individual chapters and appendices. A general discussion of each ship category, including the NOx cost-effectiveness values for POLA/POLB and the other major ports visited by the ship type, follows the table.

Table ES-3: NOx Reduction Cost Effectiveness for Cold-Ironing Ships at POLA/POLB* (Dollars/ton)

Category	All Ships	Ships with 3+ Visits	Ships with 6+ Visits
Container			
--POLA/POLB	$18,500	$14,500	15,500**
--Oakland	$56,000	$50,500	$48,500**
--Oakland w/o ship costs	$25,500	$24,000	$26,000**
Passenger	$44,000	$24,000	$17,000
Reefer	$25,000	$29,000	$32,000
Bulk	$41,000	$92,000	$55,000
Vehicle Carrier	$72,000	$75,000	$120,000
Crude-Oil Tanker	$60,000	$37,000	$33,000
Product Tanker	$110,000	$110,000	$160,000

* Assumes shore-side transformer and 0.1 percent sulfur distillate fuel.
** Cost effectiveness could improve significantly with growth in container trade and more efficient use of terminals and larger ships (see text).

Container Ships

In 2004, 592 container ships visited California ports and accounted for nearly 50 percent of the total ship visits to California. Container ships often make the first West Coast call in the Los Angeles area (the Port of Los Angeles and Port of Long Beach). Many will then stop at the Port of Oakland. In terms of container traffic, POLA/POLB processed over six times the amount of container traffic than Oakland in 2004: nine million loaded TEUs versus 1.4 million TEUs. As mentioned before, a TEU is a container with the dimensions of 20' x 8' x 8.5', and because most ocean-going containers are 40’ or 45’ long, the number of containers equals the number of TEUs divided by about 1.8.

The cost-effectiveness values for the container ship category were the best. These values ranged from $14,500 to $18,500 per ton of NOx reduced for POLA/POLB. The average cost-effectiveness values were highest when all ships were cold-ironed because ships with only one or two visits were included. These infrequent visitors have high cost-effectiveness values that drive up the average. The average cost-effectiveness values at POLA/POLB were the lowest for ships making three or more visits. The values went up slightly for ships with six or more visits because there were fewer ship visits in this category, which reduced berth utilization.

For the Port of Oakland, the average cost-effectiveness values were higher ($48,500 to $56,000 per ton of NOx reduced) because of lower average berthing times. However, if retrofitted container ships visiting cold-ironing applications at the POLA/POLB were to visit Oakland as well, Oakland would have to only add the required infrastructure to services these retrofit ships and would have no additional shipside investment cost. In 2004, 336 container ships visited POLA/POLB as well as Oakland. Assuming these ships were retrofitted for POLA/POLB, the “Oakland without ship costs” scenario would improve the cost-effectiveness values to $24,000 - $26,000 per ton of NOx reduced.

Since 2000, container traffic has increased by 40 percent at the ports of Los Angeles and Long Beach, and by 2020, cargo movement at California's ports is expected to triple from 2005 levels. Much of this growth is based upon the expected increase in imported products from Asia. Container traffic at the Port of Los Angeles and Port of Long Beach will continue to see the highest levels of overall growth. Larger and larger container ships are being built to handle this expansion. These ships will require larger auxiliary engines to handle the increased power demands of the ships and will also require longer berthing times to load and unload the containerized cargo. Both of these factors will act to significantly improve the cost effectiveness for cold-ironing container ships in California.

For example, if the number of TEUs unloaded at a specific terminal were to double (consistent with the expected average growth rate in the next ten years), the cost effectiveness of cold-ironing that terminal could improve by 10 to 75 percent. The range depends on if the increased activity were handled by more ships, larger ships, or a combination of the two. Two key assumptions are that the shore-side costs for both scenarios are comparable, and the cost of electricity is about the same as the cost of using 0.1 percent sulfur distillate fuel in the auxiliary engines—both likely scenarios. Therefore, for approximately the same overall costs, the emission reductions achieved by cold-ironing the more active terminal can more than double, resulting in cost-effectiveness values reduced by more than half.

Passenger Ships

The passenger-ship category is one of the smallest, with only 44 ships visiting California in 2004. The vast majority of the passenger ships visit the ports of San Francisco, Los Angeles, Long Beach, and San Diego.

Unlike most ship categories, passenger ships mostly use diesel-electric power systems. Propulsion is typically provided by several diesel engines coupled to generators, which drive the propellers that move the vessel. The same engines that are used for propulsion are also used to generate auxiliary power onboard the vessel for lights, refrigeration, etc.

Passenger ships typically dock in the morning and set sail in the evening. The average time in dock is about ten hours. Passenger ships have the highest power consumption while hotelling of any vessel type: five to eleven megawatts for large vessels. Since the short docking time occurs only during the day, utility rates are usually at peak or near-peak rates.

Overall, the cost-effectiveness values for cold-ironing passenger ships are among the most attractive. The average values for POLA range from $17,000 to $44,000 per ton of NOx reduced (see Table ES-3), with the highest cost representing cold-ironing all passenger ships that visit the port. Long Beach has the most attractive cost-effectiveness values because it has only one berth and has frequent visitors. San Diego is the least cost-effective because it has four berths and higher utility rates. As with container ships, the average cost-effectiveness values are highest when all ships are cold-ironed because ships with only one or two visits are included. Average cost-effectiveness values improve if fewer passenger ships are cold-ironed because the infrequent visitors are not required to retrofit their on-board power systems. For example, if San Diego were to cold-iron one berth and service ships that visited six times or more annually, its cost-effectiveness values would improve from $58,000 to $21,000 per ton of NOx.

The cruise-line industry has grown tremendously in California. The number of passengers increased 35 percent from 2003 to 2004. The Port of San Francisco expects nearly 250,000 cruise passengers in 2006—a 194 percent increase in passengers from 2004. The Port of San Diego is also projecting increases in passenger ship visits in the future.

Reefer Ships

Refrigerated cargo ships (reefers) carry perishable products, such as fruit and meat, to and from California. The products, usually palletized, are stored in large cold-storage cargo holds. Reefers currently visit the Ports of Hueneme, Los Angeles, and San Diego. Because of the special needs for the cargo that is delivered (bananas, other fruit, meat), reefers generally go to the same ports and to the same terminal at these ports. Fifty-five reefer ships visited California ports in 2004, representing only three percent of the total ship visits to California; however, many of these ships visited often.

Staff examined two electrical loads for reefers: 1 megawatt (MW) and 2 MW. In every scenario, the 2-MW case was more cost effective than the 1-MW case because emissions reductions doubled for the same capital costs and only a 15-percent increase in operating costs (mainly from the increased power consumption).

The average cost-effectiveness values for cold-ironing 2 MW reefers (the more typical case) at POLA ranges from $25,000 to $32,000 per ton of NOx (see Table ES-3). San Diego had even better average values while Hueneme was the most attractive, with average values ranging from $8,100 to $8,800 per ton of NOx reduced. As a category, reefers have some of the most attractive cost-effectiveness values among all ship categories. For example, cold-ironing reefer ships and their respective berths at the Port of San Diego and the Port of Hueneme may be the most cost-effective ship category/port combination in California, based on the 2-MW power level.

<u>Tankers</u>

Tankers carry liquid and gaseous products. The major products transported include crude oil, finished petroleum products, and chemicals. In 2004, 370 tankers visited California ports, accounting for almost 20 percent of the total ship calls. Ten percent of these tankers made at least six annual visits. Most of this activity supports the operation of California's refineries. Overall, tankers visited ports in the Los Angeles area 55 percent of the time and ports in the Bay Area the other 45 percent of the time.

There are several different types of tankers, although they can be broadly described as either crude-oil tankers or product tankers. Within the crude-oil tanker category, the tankers can either be diesel-electric, where onboard generators provide power to large electric motors for both propulsion and cargo-pumping requirements, or non-diesel-electric, where, regardless of the means of propulsion, the cargo pumps are driven by steam turbines. Diesel-electric tankers can have high electrical demands while at berth, up to 5 MW. Non-diesel-electric tankers' electrical demands at berth are much lower, between 500-800 kW, since the product pumping activity does not involve the auxiliary engines. Finally, product tankers electrical demand ranges between 0.5 MW, when material is pumped to the ship, to 2 MW, when material is pumped from the ship.

Only five diesel-electric crude-oil tankers currently visit California, and two more are under construction. Of these seven, only two are expected to be frequent visitors, calling on the Port of Long Beach at least six times annually. The range of cost effectiveness is considerable, and is dependent on the number of visits to the port. If the two cold-ironed tankers are dedicated exclusively to the Port of Long Beach, the tankers can make as many as 22 annual visits, resulting in very attractive cold-ironing economics. Conversely, if the cold-ironed tankers are not dedicated to Long Beach, but are operated as members of a West Coast fleet, they may not visit Long Beach more than six times annually, resulting in high cost-effectiveness values.

The average cost-effectiveness for non-diesel electric crude tankers visiting POLA/POLB ranges from $33,000 to $60,000 per ton of NOx reduced, depending on the number of visits (see Table ES-3). For the diesel-electric crude-oil tankers, the NOx cost-effectiveness value is $28,000 per ton reduced.

The cost-effectiveness values for product tankers are about 80 percent higher than crude-oil tankers. Product tankers spend less time at berth, they move between berths, unloading *and* loading products, and half of product-tanker visits are attributed to ships visiting one or two times. The NOx cost-effectiveness values for product tankers varied from $20,000 per ton at Richmond to $400,000 per ton at Hueneme. POLA/POLA values ranged from $110,000 to $160,000 per ton of NOx reduced (see Table ES-3).

<u>Bulk and General Cargo</u>

Bulk and general cargo ships carry material that is not easily placed into containers. Examples of materials that a bulk or general cargo ship could transport include rolls of steel, large machines, gypsum, and wood products. In 2004, bulk and general cargo ships visit all ports in California and had the largest population of ships among the six ship categories. However, out of 618 bulk and general cargo ships that visited California in 2004, only 11 of these ships made six visits or more, and they visited seven different ports. Many ships in this category made only one or two visits.

Bulk and general cargo ships have modest power needs, and those needs depend on whether the ships have onboard cranes that are used frequently. Power requirements can vary from 300 kW up to over 1 MW for ships equipped with cranes. Average hotelling time is comparable to container ships.

The cost-effectiveness values for bulk and general cargo ships varied widely, especially when considering cold-ironing all ships, ships making three or more visits, or ships making six or more visits. Bulk ships making three or more visits accounted for only 31 percent of the total bulk ship visits to California, and bulk ships making six or more visits accounted for only 11 percent of the total bulk ship visits.

For POLA/POLB, the NOx cost-effectiveness values for bulk ships varied from $41,000 to $92,000 per ton (see Table ES-3). The higher figure assumes that 32 berths are cold-ironed for ships visiting three times or more annually. The lower figure represents all bulk ships being cold-ironed.

Average cost-effectiveness values for bulk ships can be misleading, especially considering the few frequent visitors. Specific shipping scenarios at specific berths may warrant a closer examination. A focused application to dedicated ships would improve the economics of cold-ironing some bulk and general cargo ships.

<u>Vehicle Carriers</u>

Vehicle carriers are specialized ships where vehicles are driven on and off the ship. This category also includes other ships where cargo can be rolled on and rolled off (e.g., RORO). In 2004, 227 vehicle carriers visited California ports, accounting for about eight percent of the total ship visits to California. Fourteen of these ships visited six times or more. Vehicle carrier ships principally visit POLA/POLB, Hueneme, and San Diego, and to a lesser extent Carquinez, Richmond, and Oakland.

As a category, vehicle carriers are much less attractive candidates than other ship types to cold-iron. Few ships visit a port often, and their power requirements are modest compared to other types of ships. The average cost-effectiveness values for vehicle carriers visiting POLA/POLB ranges from $72,000 to $120,000 per ton of NOx reduced (see Table ES-3), with the highest value representing cold-ironing only those ships visiting the port six or more times. Vehicle carrier ships visiting six or more times had the highest average cost-effectiveness values because there were so few ships that met this criterion. The NOx cost effectiveness for cold-ironing all vehicle carriers varies from $60,000 per ton at Hueneme to $81,000 per ton at Richmond. If only ships making three or more visits are cold-ironed, these figures increase to $68,000 and $99,000, respectively.

ESTIMATED EMISSIONS REDUCTIONS AND TOTAL CAPITAL COSTS

Table ES-4 shows the potential emission reductions from cold-ironing at California ports, based on 2004 activity data and the use of 0.1 percent sulfur distillate fuel, as will be required in 2010 by ARB's recently adopted fuel regulation for auxiliary engines on ocean-going vessels. The table shows potential emission reductions if all ships are cold-ironed, if only those ships with three or more visits to a California port are cold-ironed, and if only those ships with six or more visits to a California port are cold-ironed.

Table ES-4: Impact of Cold-Ironing on Emission Reductions				
	NOx (TPD)	**PM (TPD)**	**HC (TPD)**	**SOx (TPD)**
Emissions after Auxiliary Fuel Regulation is Implemented	22.5	0.7	0.6	1.6
Emission Reductions All Ships	22.4	0.4	0.6	0.7
Emission Reductions 3+ Ships	17.1	0.4	0.5	0.5
Emission Reductions 6+ Ships	12.3	0.2	0.3	0.3

Cold-ironing the ships that make three or more annual visits—the most likely scenario—would reduce NOx emissions an additional 75 percent and PM emissions by an additional 55 percent over emissions reductions achieved through the use of clean distillate fuel.

Table ES-5 shows the emission reductions based on ship category, for ships making three or more visits to a California port. Over 60 percent of the total emissions reductions would come from the container-ship category. The next highest category, passenger ships, would provide another 10 percent of the total reductions.

Table ES-5: Emission Reductions from Cold-Ironing by Ship Category (for Ships with 3 or More Visits to a California Port)				
Category	**NOx (TPD)**	**PM (TPD)**	**HC (TPD)**	**SOx (TPD)**
Container	10.8	0.18	0.34	0.19
Bulk	1.4	0.02	0.04	0.04
Passenger	1.7	0.04	0.05	0.03
Reefer	1.4	0.1	0.04	0.21
Product Tanker	0.7	0.02	0.02	0.05
Vehicle Carrier	0.5	0.01	0.01	0.01
Crude-Oil Tanker	0.6	0.01	0.01	0.01
Total	**17.1**	**0.38**	**0.51**	**0.54**

Ship traffic to California ports is expected to grow substantially in the next few years. Container ships will lead this growth. Container ships already represent about half of the total visits by ocean-going vessels, and the visits are expected to increase by 50 percent from current levels by the end of the decade and double by 2020.

Table ES-6 provides ARB staff's estimates of NOx and PM emissions from hotelling for 2004 and projected emissions for 2010, 2015, and 2020. The 2004 estimate is based on the current fuel mix (mostly residual), and the future year estimates is based on the use of 0.1 percent sulfur distillate, as required by the recently adopted ARB rule governing auxiliary engines. By 2010, the hotelling emissions for PM are substantially reduced, but emissions of NOx have increased by 40 percent—consistent with our knowledge that switching from the current fuel mix to a distillate fuel will result in substantial reductions in PM, but relative modest benefits to NOx. By 2020, because of the expected growth in activities at California ports, the emissions of NOx have more than doubled from 2004 levels, while the emissions of PM have increased by 50 percent from 2010 levels.

Table ES-6: Future Hotelling Emissions from Ocean-Going Vessels (TPD)

Year	NOx	PM
2004	24.2	2.1
2010	34.5	0.9
2015	44.0	1.15
2020	53.4	1.4

Figure ES-1 graphically describes the impact of cold-ironing on hotelling NOx emissions. Staff assumed that cold-ironing would reduce ship hotelling emissions by 20 percent, 60 percent, and 80 percent by 2010, 2015, and 2020, respectively. This level of activity for cold-ironing is consistent with the draft *Emission Reduction Plan for Ports and International Goods Movement in California*. By 2020, when 80 percent of hotelling emissions are assumed to be reduced from cold-ironed, NOx emissions would be reduced by 41 tons/day. Between 2008 and 2020, cold-ironing could reduce emissions from hotelling by 100,000 tons.

Figure ES-1: NOx Reductions from Cold-Ironing

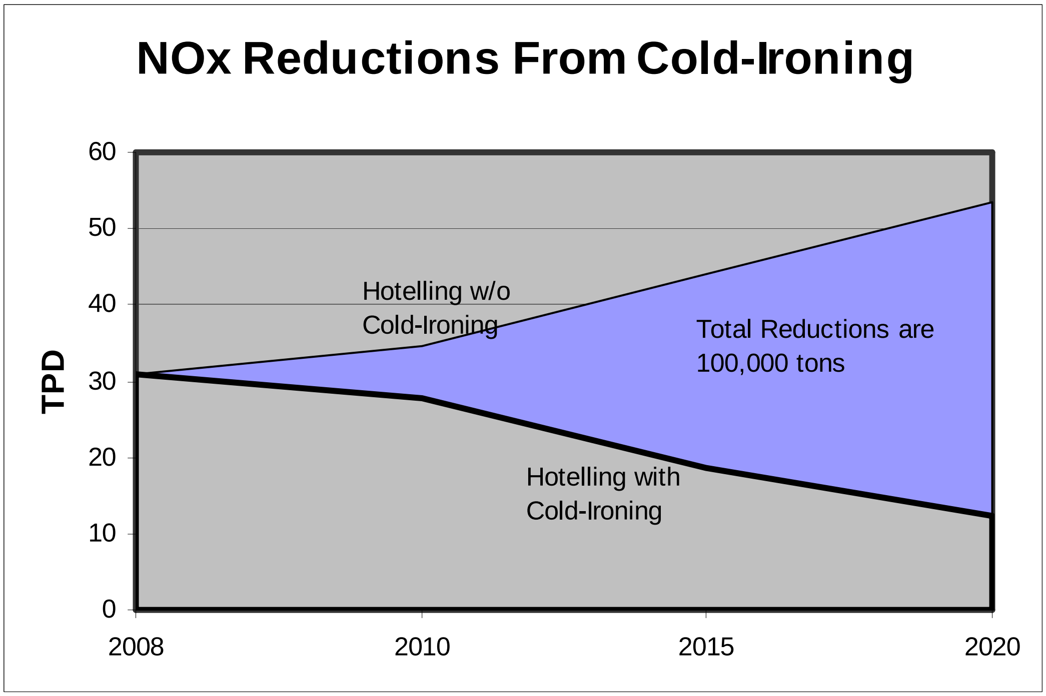

Table ES-7 numerically expresses the emissions reductions contained in Figure ES-1 as well as shows the projected PM emission reductions for the same years.

Table ES-7: Potential Emission Reductions from Cold-Ironing Ocean-Going Vessels (TPD)

Year	NOx	PM
2010	6.6	0.16
2015	25.3	0.62
2020	41	1.01

For 2010, staff assumed a 20 percent emissions reduction could be satisfied by cold-ironing a modest percentage of container ships, as well most of the passenger ships and reefer ships that make at least three annual visits to a California port. By 2015, staff assumed a 60 percent emissions reduction could be satisfied if all container, passenger and reefer ships making three or more visits to a port were cold-ironed. By 2020, a 80 percent emissions reduction could be satisfied if either all of the bulk cargo and vehicle carrier ships making three or more visits to a port were also cold-ironed—an unlikely scenario—or additional emission reductions were found in the container, passenger, and reefer ship categories.

Table ES-8 shows the total capital costs, by ship category, for cold-ironing ships making three or more visits to a California port, based on 2004 data.

Table ES-8: Capital Cost to Implement Cold-Ironing by Ship Category (for Ships with 3 or More Visits to a California Port)* (Million Dollars)

Category	Shore-Side	Ship-Side	Total
Container	$180	$210	$390
Bulk	$150	$64	$214
Passenger	$38	$11	$49
Reefer	$17	$12	$29
Product Tanker	$90	$22	$112
Vehicle Carrier	$28	$31	$59
Crude-Oil Tanker	$40	$21	$61
Total	**$543**	**$371**	**$914**

* Assumes shore-side transformer.

Table ES-9 provides the costs based upon the commodity being affected. The cost to cold-iron container ships ranges from $4 to $13 per loaded TEU. The high end of the cost represents cold-ironing all container ships at Oakland. The low end of the cost represents cold-ironing container ships making six or more visits to POLA/POLB. These cost estimates are calculated by dividing the annualized cost of cold-ironing the ships being considered by the total units of that item moved during 2004. For example, the estimated annualized cost for cold-ironing the container ships making six or more visits to POLA/POLB is $60 million. During 2004, about nine million loaded TEUs were shipped through POLA/POLB. Therefore, the TEU unit cost is $60 million divided by nine million TEUs, or $6.66 per TEU. This cost is slightly more than one percent of the cost to ship a container freight across the Pacific, which is about $500 per TEU.

For the passenger-ship category, the cost to cold-iron represents about one to five percent of the cost of a cabin for a typical three-day or seven-day cruise.

Table ES-9: Costs for Cold-Ironing Based on Commodity

Container Ships	$4-13 per TEU (loaded only) $4-10 per TEU (loaded and empty)
Passenger Ships	$12-16 per passenger

When the capital costs for implementing cold-ironing are examined on a commodity basis, cold-ironing is expected to have minimal impact on consumer costs.

Table ES-10 shows the projected total statewide electrical impact for cold-ironing for 2010, 2015, and 2020, assuming levels of cold-ironing activities that would reduce ship hotelling emissions by 20 percent, 60 percent, and 80 percent, respectively. As expected, the Ports of Los Angeles and Long Beach would have the highest electrical demand.

Table ES-10: Estimated Peak Power Demand for Cold-Ironing, by Port (MW)

Port	2010	2015	2020
Carquinez	0	0	5
Hueneme	4	5	13
Los Angeles/Long Beach	92	360	523
Oakland	2	91	110
Richmond	0	0	2
San Diego	55	89	140
San Francisco	37	62	100
Total	**190**	**607**	**893**

The current peak statewide energy demand is approximately 57,000 MW during the summer months and is expected to grow to about 75,000 MW by 2020. The electricity demand from cold-ironing implementation would represent about one percent of the total energy peak demand.

According to the California Energy Commission in 2004, the energy and capacity necessary to serve cold-ironing at California ports are not likely to cause a significant impact to the electricity system although new generation will be needed to meet expected loads in the future, with or without cold-ironing. Peak-pricing and interruptible-program participation could further reduce the impact to the electricity system at lower cost.

In the near term, there still exists some reserve-capacity issues in the State, especially under hot-weather conditions. Furthermore, regional and local transmission congestion may limit some resource options.

POSSIBLE FUNDING SOURCES

The infrastructure for cold-ironing will require significant capital investment. There are several options for paying these costs, including traditional regulations, public financing in the form of incentives, bonds, or other subsidies, and user-based fees.

In recent years regulatory programs in some sectors have been supplemented with incentives to accelerate voluntary actions, such as replacing older equipment. Incentive programs like the Carl Moyer Program are both popular and effective but require the allocation of public funds, which are in limited supply. California is currently investing up to $140 million per year to clean up older, higher emission sources. However, it is likely that Carl Moyer Program funds used for port-related goods movement emissions will focus on efforts to reduce diesel emissions through vehicle retrofits or upgrades and, thus, not be a significant source of money for cold-ironing projects.

A far more likely source of public funding for some portion of cold-ironing is the use of state general obligation bonds issued to generate revenues for a special port-related incentive program. Governor Schwarzenegger has proposed $1 billion in bonds to be matched by another $1 billion in funding from other sources to reduce goods-movement related pollution.

However, even if public funding becomes available, ARB staff presumes that traditional regulations, user fees, or port lease requirements (which place the costs of control on the owners and operators of polluting sources) will provide a large share of progress needed to deploy cold-ironing.

The ports, through their policies and lease agreements, can provide incentives for cold-ironing, such as is being done for the Port of Los Angeles Alternative Maritime Power (AMP) program. The Port supports this program in part by providing incentives to container- and passenger-ship operators to retrofit their vessels for shore power. Similar efforts are underway at the Port of Long Beach.

Federal funding is one funding mechanism currently being used or considered at the ports to implement cold-ironing projects. The U.S. EPA has provided several small grants thus far, through the West Coast Clean Diesel Collaborative, for California goods movement-related projects. The Collaborative seeks funding for a variety of port projects, including cold ironing applications. For example, in 2004, the U.S. EPA issued a $50,000 grant for a cold-ironing application at the Princess Cruises terminal in Seattle. Another potential project the Collaborative has identified is funding a shore-power installation at the new passenger terminal at the Port of San Francisco, if the Port goes forward with this option.

CONCLUSIONS

Based on the results of this cold-ironing study, ARB staff believes several conclusions are warranted:

- It is feasible to cold-iron ocean-going vessels visiting California ports, as ships of various types and designs are already connecting to shore power at California ports and other cold-ironing installations are already planned.

- Cold-ironing could produce large emission reductions and is cost-effective at a large number of terminals and for a large percentage of ship visits. The most attractive ship categories are container ships, passenger ships, and reefers. Cold-ironing container ships and passenger ships is especially crucial for emissions reductions, as these ships account for 56 percent of all ship visits to the State, and container shipments and passenger ship visits are both growing dramatically.

- As shipping volumes increase, the emission reductions achievable from cold-ironing increase dramatically, and the cost effectiveness of the strategy also improves.

- There are cases when cold-ironing, while feasible, may not be cost effective, such as for ships with infrequent and irregular visits to California, especially for those vessels with lower power needs and shorter berthing times.

- Cold-ironing will require significant infrastructure investment by both the ports and the shipping companies.

- Cold-ironing will increase peak electrical demand, but the increase can be absorbed by the State's power system.

- The cost-effectiveness values in this report assume that all of the costs and the benefits will be borne by California. As cold-ironing becomes commonplace, other ports—whether U.S. or foreign ports—will reap the benefits of cold-ironing when they install the necessary infrastructure to service the ships retrofitted to cold-iron in California. As this happens, some of the ship-side costs allocated to emission reductions in California should more properly be allocated to these other ports. This would further improve the cost-effectiveness of this technology for use in California.